VARIABILITY VS. UNIFORMITY IN THE TROPICS

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IT is commonly stated that tropical climates are extremely uniform. This is only partly true. They indeed have comparatively slight seasonal variations in temperature and in the length of day and night, and large areas have rather steady winds much of the time. But continual emphasis upon the uniformity of tropical climates is misleading because there are important variations in temperature and wind, while the rainfall of the lower latitudes appears to be more variable on the average than the rainfall of higher latitudes. There likewise appears to be more variation in storminess and in rapid change of air pressure than in higher latitudes.

Recent field investigations (financed by the Bishop Museum of Honolulu and Yale and Indiana Universities) in Hawaii, Fiji, tropical Australia, the East Indies, the Philippines and tropical China, and examination of official meteorological records concerning these areas and others have disclosed interesting evidences of tropical variability and have convinced me that the conventional statements, based on averages, are sufficiently misleading to make it worth while to emphasize the climatic variability occurring in the tropics.

The small seasonal contrasts in temperature which are characteristic of the tropics are perhaps the chief reason why the impression has been gained that tropical climates are uniform in other respects. Another reason for this common belief is the fact that the climatic data concerning the tropics are chiefly available in the form of averages. Averages by themselves are very misleading and should be supplemented as soon as possible by statements as to extremes, and as to normal extent of departure from means.

Although the average seasonal range in temperature is indeed small in low latitudes as compared with middle latitudes, there is an appreciable seasonal contrast in latitudes more than 10° or 15° from the equator. Indeed some parts of the tropics have about as great a seasonal range of temperature as certain especially uniform parts of higher latitudes. This is illustrated when the average

differences in mean temperature between the three warmest months and the three coolest of the following pairs of seaport cities are compared. Some of the cities in the right-hand column are not within the tropics according to the narrowest limitation of that zone. However, all are within the belt dominated by the Trades during most of the year, which is the belt commonly considered as tropical.

TABLE 1

SEASONAL RANGE OF TEMPERATURE

Calcutta,	range 18° F., vs.	Dublin,	range 17° F., 22° N. vs. 53° N.
Hongkong,	range 20° F., vs.	Glasgow,	range 12° F., 22° N. vs. 56° N.
Brisbane,	range 17° F., vs.	Hobart, Tas.	range 15° F., 27° S. vs. 43° S.
Durban,	range 11° F., vs.	Dunedin, N. Z.,	range 14° F., 29° S. vs. 46° S.
Cairo,	range 16° F., vs.	Bergen, Nor.,	range 22° F., 30° N. vs. 60° N.
New Orleans,	range 26° F., vs.	Vancouver,	range 22° F., 30° N. vs. 49° N.
Madras,	range 9° F., vs.	San Francisco,	range 8° F., 13° N. vs. 38° N.
Naples,	range 25° F., vs.	London,	range 22° F., 41° N. vs. 51° N.

Even in regard to extremes of temperatures, some cities in fairly low latitudes have ranges which approach those of the less variable parts of the relatively high latitudes. This is illustrated by the following table showing the difference between the highest and lowest temperatures ever officially recorded at certain pairs of seaport cities up to a recent year.[1]

TABLE 2

EXTREME RANGE OF TEMPERATURE

Calcutta,	range 64° F., vs.	Dublin,	range 74° F., 22° N. vs. 53° N.
Hongkong,	range 65° F., vs.	Glasgow,	range 78° F., 22° N. vs. 56° N.
Bombay,	range 54° F., vs.	Lisbon,	range 62° F., 19° N. vs. 40° N.
Madras,	range 55° F., vs.	San Francisco,	range 72° F., 13° N. vs. 38° N.
Rio de Janeiro,	range 52° F., vs.	Wellington,	range 58° F., 23° S. vs. 42° S.
Brisbane,	range 73° F., vs.	Hobart, Tas.,	range 78° F., 27° S. vs. 43° S.
Durban,	range 71° F., vs.	Dunedin, N. Z.,	range 71° F., 29° S. vs. 46° S.
Cairo,	range 82° F., vs.	Bergen, Nor.,	range 84° F., 30° N. vs. 60° N.
New Orleans,	range 95° F., vs.	Sitka,	range 90° F., 30° N. vs. 57° N.
Capetown,	range 68° F., vs.	Amsterdam,	range 86° F., 34° N. vs. 52° N.

That there are appreciable seasonal contrasts in temperature in lower latitudes is not surprising when the seasonal variation in insolation is considered. In spite of the fact that the sun shines vertically somewhere between the two tropics every day in the year, there is a great change in angle of incidence. Few people realize that when the sun is vertically over the northern tropic

[1] References to sources of data are given in a longer, more technical article on "Variability of Tropical Climates" to be published in *The Geographical Journal* (London).

(Cancer), it shines upon the southern tropic (Capricorn) less nearly vertically by 4 degrees than upon the Arctic Circle. The latitude of New York receives much more heat from the sun on June 21 than does the equator, for not only is the sun six degrees more nearly vertical than at the equator, but moreover the days are almost four hours longer.

Although on the average tropical regions show less contrast in seasonal change of temperature than do middle latitudes, the reverse is true in respect to daily range. The night has been called the winter of the tropics. The daily range is considerable in all lower latitudes, although it is less in the more humid regions than in the more arid. On the average it is distinctly greater than the normal range in higher latitudes. This is due to two chief influences: Day and night are more nearly equal in length, and hence there is a closer balance between the duration of the heating and cooling periods than occurs in higher latitudes, where the nights are too short in summer for marked cooling and the days are too short in winter for effective heating. The other great cause is the higher average temperature, since the escape of heat varies as the fourth power of the absolute temperature. This means that normally there is much greater cooling per nocturnal hour wherever the day-time temperature is high than where it is low. A third reason why the diurnal range averages greater in low latitudes (below 30°) is that a larger proportion of the area is arid or semi-arid than is the case in middle latitudes.

In the tropics the nights often become so cool that considerable discomfort results. Even in an insular climate like that of Suva, Fiji (latitude 18°S.), in spite of the wind blowing off the sea, and a rainfall of over 100 inches fairly evenly distributed throughout the year, it commonly becomes so cool at night that the sensitive residents wear wraps if they walk out late in the evening. Indeed, even the heavy army overcoats are frequently worn with comfort at night and in the early morning during the cooler season. In drier parts of the tropics, the nights become much cooler than in a humid locality like Suva. On the dry western sides of the Fiji Islands, for example, temperatures below 40°F. have been recorded near latitude 16° close to sea level, and in dry continental areas frost is not unknown near sea level, as for example within 20° from the equator in Australia and Africa.

Another type of marked cooling in the tropics is the sudden drop, often as much as 6° or 8°F., which occurs in thunder-storms, which are very frequent in many parts of the tropics, far commoner on the average than in higher latitudes. Sometimes, as when hail falls in quantity, the temperature-drop is much greater.

Hail storms are not very rare in some tropical localities. For example, ten hail storms were reported in ten years in latitudes 13° to 16° S., near sea level in the Northern territory of Australia. Three hail storms occurred in Panama (latitude 9°) in a twelve year period.

Cold snaps of still other types occur within the tropics. For instance, cold winds sometimes sweep down from higher latitudes and bring low temperatures surprisingly near the equator. Zero temperatures have been officially recorded in subtropical Northern Florida (lat. 30° N.), and a temperature of only 10° above zero F. has occurred on the Gulf Coast of Mexico in latitude 25½° N. Central coastal Queensland is subject to "severe frosts" during four months in the year within 21° of the equator, while freezing temperatures have occurred even in the day time in southeastern Asia in latitude 22° at sea level. Still farther south, on the China Sea near Manila, latitude 15°, for example, northerly gales in winter occasionally make overcoats welcome even in the day time. Similar cold snaps occur in the cooler months in other tropical localities such as the Hawaiian Islands, Jamaica and Fiji. Indeed, remarkable as it may seem, the Weather Bureau reports a snow flurry practically at sea level at Mahukona, Hawaii (lat. 20° 11′), lasting ten minutes on December 29, 1921. Perhaps even more surprising is the great cooling reported as not rare in winter on the coast of Venezuela, in latitude 10° N. Director Ugueto, of the Cajigal Observatory, announces that gales from the north off the sea occasionally bring temperatures of 45° F. or even less, in the day time, lasting a number of days. They are not associated with thunderstorms, for the sky is clear at the time.

Because of the sensitiveness of the residents of the tropics to low temperatures, chills and colds often develop and sometimes pneumonia. Many observers have been impressed by the abundance of coughs and catarrh in the tropics. They may be more common there than in Canada. Indeed there is considerable truth in the saying that "cold causes more suffering in the tropics than in polar or subpolar regions."

Now as to the winds: Five chief sorts of variation within the tropics merit attention: (1.) Even when the direction is fairly constant, there is a marked diurnal variation in velocity. Calm nights are the rule in trade wind deserts and nearly calm nights are common elsewhere on the land except upon exposed elevations. Likewise at sea, while the diurnal range is less than on land, it is notable. For example, Tetens reports a diurnal range of over 50 per cent. in the velocity of the wind at Samoa. In higher latitudes, while the wind frequently dies down at nightfall, and normally

weakens, windy nights are by no means uncommon, and very frequently the wind is stronger by night than by day. In the tropics, windy nights occur on lowlands only during the passage of rather rare severe cyclonic storms. Moreover, disturbances of an intensity which would give strong nocturnal winds in middle and high latitudes cause only moderate winds at night at low elevations in the tropics. This is due to the influence of the comparatively great decrease in vertical convection at night in low latitudes caused by the greater cooling of the surface air than of the overlying free air. It is for this reason also that even relatively steep barometric gradients in monsoonal regions permit a marked dying down of the surface winds at night.

(2.) Seasonal as well as diurnal variations in the velocity of the trades are common. "Half Gales" are characteristic of Fiji, the New Hebrides and many other South Pacific groups in their spring months, and even "whole gales" are frequent during the northeast "monsoons" in the China Sea during winter. On the other hand, in other months calms or light breezes are the rule when the doldrums migrate past, as they do twice each year with the seasonal change in the altitude of the sun. Along the margins of the tropics calms likewise occur when the extra-tropical belt of high pressure migrates equator-ward in the cooler season.

(3.) There is a radical seasonal change in the direction of the Trades when they cross the equator; those crossing from the north change from east-northeast winds to northwest, due to the deflective effects of the earth's rotation. Consequently many places near the equator have easterly winds much of the year; calms while the doldrums are migrating past, and westerly winds when the doldrums are situated in higher latitudes on their side of the equator. Then, as the sun returns equator-ward, calms and easterlies recur.

(4.) Another evidence of tropical variability is that land and sea breezes are more characteristic of the lower latitudes than of the higher. This is because the contrast in the temperature of land and water averages greater in low latitudes. Indeed while in middle and high latitudes sea breezes are rare except during the hottest weeks, in many parts of the lower latitudes they occur almost every day in the year, and give a wind régime which is very different from the constant easterly trades supposedly characteristic of the tropics. The monsoons are a special type of land and sea breezes, since they blow towards the land for many consecutive weeks during summer, and in the opposite direction in winter. While produced by temperature contrasts of extra-tropical regions, the monsoons are most strongly felt in tropical latitudes (below

30°) and give large and important regions a sharp seasonal contrast in wind directions. Between the winter and the summer monsoons, there commonly is a spell some weeks in length when the winds are irregular and often light. After they become steady in direction they often fluctuate notably in velocity from day to day as well as between day and night.

(5.) Although winds due to cyclonic disturbances do not occur so frequently within the tropics as in higher latitudes, they are significant. The "boxing of the compass," during which the wind comes from every direction in turn, occurs many times a year in most parts of the tropics, while occasionally cyclonic gales or even violent hurricanes occur. Official Japanese daily weather maps and annual summaries of storm tracks show an average of over fifty tropical cyclonic disturbances a year in east longitudes 115°-145°, while a study of the Australian daily weather maps for 20 years shows an average of over 30 a year in similar longitudes south of the equator. Thus in less than one seventh of the circumference of the earth there are over 80 cyclonic disturbances in an average year. This is, however, the stormiest sector.

Mention should be made of thunder squalls which are, on the average, more violent in low latitudes than in higher latitudes and more frequent. In addition, several regions in subtropical latitudes experience tornadoes or similar storms. Thus it is evident that there is considerable variation in respect to winds in the tropics.

Variations in rainfall have perhaps even greater significance than variations in temperature or wind. The indications are that in respect to dependability of precipitation, the lower latitudes are notably less fortunate than are middle latitudes. In order to compare the variability of rainfall in the tropical half of the globe with that of the higher latitudes, I have inspected the official records for many cities in both zones. The selection was impartial, being determined solely by whether or not the data were available. The comparison is between the greatest and least annual precipitation officially recorded before a recent year. The length of the record varies, but in general it is shorter in low than in higher latitudes and hence tends to lessen the apparent range in lower latitudes. Tables 3 and 4 give the figures to the nearest one tenth of an inch. It will be noticed that the maximum amount of rainfall received in a year was less than twice the minimum for Chicago, Christiania, Edinburgh, Ottawa, Paris, Pekin and Tokio, and only a trifle more than twice the minimum in the case of Amsterdam, Berlin, Berne, London, New York, Petrograd, St. Louis, Vienna and Wellington, N. Z. Very few middle or high latitude cities appear to have ex-

perienced three times as much precipitation in their wettest year as in their driest. Madrid, Washington, D. C., and Vladivostock are exceptions as are some cities in southern Europe, while Hobart, Tasmania, Buenos Aires, Rome and San Francisco are notable for having received about four times as much. However, many geographers class Buenos Aires, Rome and San Francisco as subtropical. Furthermore, Madrid and Vladivostock have an average rainfall of less than 20 inches, and thus are more subject to large percentage changes than is the case where the normal rainfall is larger.

TABLE 3

EXTREME ANNUAL RANGE IN RAINFALL IN MID-LATITUDES

City	Latitude	Average Rainfall	Driest Year	Wettest Year
Amsterdam	52° N.	27.3 in.	17.6 in.	40.6 in.
Berlin	52° N.	23.0	14.3	30.0
Berne	47° N.	36.3	24.7	58.2
Buenos Aires	35° S.	36.8	21.5	80.7
Chicago	42° N.	33.5	24.5	45.9
Christiania	60° N.	22.5	16.3	31.7
Edinburgh	56° N.	25.2	16.4	32.1
Hobart	43° S.	23.7	13.4	43.4
London	51° N.	24.0	18.2	38.2
Madrid	40° N.	16.2	9.1	27.5
New York	41° N.	42.5	28.8	59.7
Ottawa	45° N.	33.4	26.4	44.4
Paris	49° N.	21.9	16.4	29.6
Pekin	40° N.	24.4	18.0	36.0
Petrograd	60° N.	21.3	13.8	29.5
Rome	42° N.	32.6	12.7	57.9
San Francisco	38° N.	22.8	9.3	38.8
St. Louis	39° N.	37.4	23.4	49.2
Tokio	36° N.	59.2	45.7	77.1
Vladivostock	43° N.	19.5	9.4	33.6
Vienna	48° N.	24.5	16.5	33.9
Washington	39° N.	43.8	18.8	61.0
Wellington, N. Z.	42° S.	49.7	30.0	67.7

Turning now to the lower latitudes: Among 20 scattered cities selected impartially, in no case was the officially recorded rainfall of the wettest year less than twice that of the driest. Only in Calcutta and Caracas did the ratio fall as low as 2¼. In Johannesburg it was 2½ times as great, and in Durban, Hongkong and New Orleans it was 2¾. In Colombo and Honolulu it was about 3; in Bombay, Buenos Aires and Manila each about 3½; in Madras 4½; in Brisbane and Singapore 5; and in Rio de Janeiro 13.4. All these cities have a normal rainfall of 30 inches or over, and the mean for the group of cities is 55.6 inches in contrast with a mean of

30.5 inches for the cities of Table 3. Since percentage fluctuations tend to become smaller as the total rainfall increases, the great fluctuations experienced by these tropical cities are all the more notable.

TABLE 4

EXTREME ANNUAL RANGE IN RAINFALL IN LOW LATITUDES

City	Latitude	Average Rainfall	Driest Year	Wettest Year
Bombay	19° N.	71.1 in.	33.4 in.	114.9 in.
Brisbane	27° S.	45.6	16.2	88.3
Calcutta	22° N.	62.0	39.4	89.3
Caracas	11° N.	30.0	23.7	47.4
Colombo	7° N.	83.8	51.6	139.7
Durban	29° S.	40.8	27.2	71.3
Hongkong	22° N.	84.1	45.8	119.7
Honolulu	21° N.	31.3	14.6	45.0
Johannesburg	26° S.	31.6	21.7	50.0
Madras	13° N.	49.0	18.5	88.4
Manila	15° N.	76.3	35.7	117.0
Naples	41° N.	34.0	21.7	56.6
New Orleans	30° N.	55.7	31.1	85.7
Rio de Janeiro	23° S.	46.8	4.7	63.5
Singapore	1° N.	92.0	32.7	158.7

If tropical and subtropical cities having an average rainfall of less than 20 inches are included in the comparison, even more violent ranges are disclosed. For example, Cairo, Egypt and San Diego, Calif., each received about 6⅓ times as much rainfall in their wettest year as in their driest; Athens 7 times; Helwan, Egypt, 18 times; and Onslow, W. Australia, 47 times as great.

None of the cities of Table 4, except Singapore, happens to be close to the equator, the necessary data for other equatorial cities not being readily available. However, extreme fluctuations occur almost under the equator even on oceanic islands. At Malden Island (lat. 4° 1′ S.; long. 154° 58′ W.), for example, the annual totals of rainfall have varied from 3.95 inches in 1908 to 63.41 inches in 1905. At Oceanic Island (lat. 0° 52′ S.; long. 169° 35′ E.), nearly 2,000 miles west of Malden Island and within a degree of the equator, the range has been between 19.61 inches in 1909 and 158.93 in 1905 (141.12 in 1911). There was likewise a range of from 74 rainy days in 1910 to 232 in 1911. Upon the Hawaiian Islands, Puuhela, on Maui, (lat. 20¾° N.; long. 156½ W.) received only 2.46 inches of rain in 1912, but received 33.14 inches in 1918. Many other Hawaiian stations show a somewhat similar range, and the rainfall of the group as a whole is characterized by the government meteorologist as "extremely unreliable."

The great variability illustrated by these three mid-Pacific Islands is the more notable because insular climates are commonly

thought to be exceptionally uniform, particularly if near the equator and not dominated by near-by continental masses, nor within hurricane regions. None of these three is in a hurricane region, all are far from land and two are close to the equator.

So many other regions in low latitudes experience an undependable rainfall that it seems unnecessary to more than mention the famines produced by droughts in India and in southern China, or the destructive floods in the same countries. Tropical Australia has perhaps even worse droughts and floods and is saved from terrible famines only by the sparseness of the population and the skill used in reducing the losses to a minimum. The annual variation at Onslow in tropical West Australia, for instance, was from 0.57 inches in 1912 to 26.96 in 1900, and the average variability from year to year in that region has been about 50 per cent. of the average rainfall.

Excessive falls in short periods afford other illustrations of the uncertainty of rainfall. In tropical Australia, on more than 400 days in a 25-year period more than 10 inches of rain fell in 24 hours according to official records, while in temperate Australia there have been very few recorded instances of such heavy rainfalls—none in Victoria or South Australia and only two in Tasmania (Max. of 18.1 inches in three days). In tropical Australia, more than 20 inches has been officially recorded as falling in 24 hours on 42 different days, and more than 30 inches on four occasions. The maximum was 35.71 inches at Crohamhurst, Queensland, Feb. 2, 1893. However, 60 inches fell in three consecutive days at Mt. Molloy, Queensland, and there have been many 48-hour periods when more than 25 inches fell.

At Suva, Fiji, it frequently happens that more than 10 inches of rain falls within 24 hours; there were 4 cases in the 7-year period 1906-12. The maximum has been 26.5 inches in less than four hours on August 8, 1906.

What is believed to be the world's record for officially measured rainfall in 24 consecutive hours occurred near Manila on Feb. 14-15, 1911 (1,168 mm., 46 inches). The other stations at which this maximum has been approached are also in low latitudes, namely, Cherrapunji, India, June 14, 1876, 40.8 inches; Silver Hill, Jamaica, 57.5 inches in 48 hours; Funkiko, Formosa, 40.7 inches on Aug. 31, 1911, and at Hononu, Hawaii, 31.9 inches, Feb. 20, 1918.

With such sharp annual and daily extremes as these, it is reasonable to expect great monthly extremes. At Malden Island, mentioned above, for example, the range in officially recorded rainfall from 1890 to 1918 was as follows:

TABLE 5

MONTHLY VARIATION IN RAINFALL AT MALDEN ISLAND

January	from	0.00 in.	to	19.48 in.
February	from	0.00 in.	to	9.27 in.
March	from	0.15 in.	to	25.65 in.
April	from	0.47 in.	to	12.34 in.
May	from	0.29 in.	to	12.30 in.
June	from	0.00 in.	to	12.49 in.
July	from	0.59 in.	to	10.10 in.
August	from	0.18 in.	to	5.56 in.
September	from	0.05 in.	to	3.03 in.
October	from	0.00 in.	to	5.27 in.
November	from	0.00 in.	to	8.72 in.
December	from	0.00 in.	to	8.20 in.

The four months, November, 1891, to February, 1892, received a total of only 0.72 inches, while the four months, January to April, 1915, received over 60 inches. The number of rainy days per year varied from 30 to 144.

At Oceanic Island, likewise, the monthly ranges are extreme. Within a nine-year period, February, March, April and November have each received 0.1 inches or less and also 21.3 inches, 28.9, 27.6 and 15.5 inches, respectively, and falls of 0.7 inches or less in May, August, September, October and December are to be contrasted with falls of from 12 to 19 inches received in other years in those same months.

The Philippines show scarcely less violent extremes. In the 16-year period, 1903-18, 42 of the 70 stations had a total of about 160 months with no rainfall, while the wettest months at about half the stations exceeded 40 inches of rain, and had less than 20 inches in the case of only 8 stations. This variation is only partly seasonal, for a month which is very dry one year may be excessively wet another. Severe and widespread droughts, with over 100 days without rain, are contrasted with destructive floods caused by rainfalls of more than 20 inches in a day or two.

Even at Hilo, on the wet side of Hawaii, where the rainfall averages 139.4 inches a year and is relatively dependable, a 13-year period shows that the monthly amounts have varied widely, January from 0.5 inches to 38.6, February from 1.9 to 32.5 inches, March 2.9 to 45.4, April 3.7 to 25.1, and December from 1.7 to 27.8 inches, for example.

That the great variation from year to year in rainfall discussed in the foregoing pages is not local is suggested by various data. For example, the average rainfall of the entire Hawaiian group (150 stations) was more than twice as great in 1919 as in 1918 (112.9 in. vs. 54.5 in.). Likewise in the Philippines during the droughts such as that referred to in a preceding paragraph, nearly all of the 70 stations are affected similarly.

Another type of variation in rainfall which is prominent in the tropics is the seasonal. Very few tropical localities receive their rainfall as evenly distributed throughout the year as is common in many parts of middle latitudes. Distinct wet and dry seasons are the rule. The rainy summers and dry winters of India and China are well known. Most of tropical Australia also receives almost no rain for six months and from 15 to 50 inches or more in the other six months. Hawaii and many other places near the margins of the tropics receive much of their rainfall in winter, while still other parts of the tropics have two wet and two dry seasons.

In order to compare the monthly variability of rainfall in low and middle latitudes, a planimeter measurement was made of Supan's map of Percentage Range of Mean Monthly Rainfall in Bartholomew's Atlas of Meteorology. This map shows four types of regions: (1) where the wettest month is less than 10 per cent. rainier than the driest month; (2) where the wettest month is from 10-20 per cent. rainier than the driest; (3) where the range is from 20-30 per cent; and (4) where it is over 30 per cent. Tables 6 and 7 show the approximate area and the percentage of each type by continents. Table 6 concerns middle latitudes (30° to 60°); Table 7 concerns low latitudes (30° N. to 30° S.).

TABLE 6

PERCENTAGE RANGE OF MEAN MONTHLY RAINFALL, LATITUDES 30° TO 60°

	Range less than 10 per cent.		Range 10-20 per cent.		Range 20-30 per cent.		Range over 30 per cent.	
	Mil. Sq. Mi.	%	Mil. Sq. Mi.	%	Mil. Sq. Mi.	%	Mil. Sq. Mi.	%
Europe	1.77	65	.88	34	.03	1	0	0
North America	2.06	43	2.62	54	.14	3	0	0
South America	.23	26	.55	60	.13	14	0	0
Asia	.22	3	2.65	34	3.75	49	1.13	14
Africa	.05	15	.23	44	.47	41	0	0
Australia	.36	47	.40	53	.005	.6	0	0
Total and Means	4.70	26	7.34	42	4.42	25	1.13	7

TABLE 7

PERCENTAGE RANGE OF MEAN MONTHLY RAINFALL, LATITUDES 30° N. TO 30° S.

	Range less than 10 per cent.		Range 10-20 per cent.		Range 20-30 per cent.		Range over 30 per cent.	
	Mil. Sq. Mi.	%	Mil. Sq. Mi.	%	Mil. Sq. Mil.	%	Mil. Sq. Mi.	%
North America	0	0	.46	39	.70	61	0	0
South America	.12	2	4.91	76	1.31	21	.04	1
Asia	.10	2	.96	23	2.56	60	.63	15
Africa	0	0	2.28	20	8.86	78	.21	2
Australia	.16	7	.63	28	1.32	59	.13	6
East Indies	.43	36	.72	63	.01	1	0	0
Total and Means	.81	3	9.76	38	14.76	55	1.01	4

It will be seen that low latitudes have over three times as large an area possessing a monthly variability of over 20 per cent. as is the case in mid-latitudes and twice as large a percentage of their total area has this range. The one large area in mid-latitudes having the fourth, the most extreme, type of rainfall variability is the Tibetan Plateau, which has little agricultural value because of its great altitude. Furthermore, the month of least precipitation in mid-latitudes commonly is in the winter when plants require little moisture while the wettest month usually is in summer. On the other hand, the driest month of the tropics is also a hot month, with active evaporation. This unfortunate combination is very hard on plants, and is the reason for the lack of forests in many places having a large annual rainfall. For instance, parts of tropical Australia having over 60 inches of rain a year possess no real forest because several months are extremely dry and hot.

In respect to the more uniform rainfall type, where the range between the driest and wettest month is less than ten per cent. mid-latitudes have nearly six times as large an area as low latitudes. This type comprises about 26 per cent. of the total land area of mid-laditudes while it makes up only 3 per cent. of low latitudes. Other interesting comparisons come out on further study of these tables.

Why should the lack of marked seasons in respect to temperature be emphasized and the presence of marked seasons of rainfall be largely ignored by most writers on the tropics?

Another climatic factor subject to marked changes is storminess. Cyclonic storms are erratic in all parts of the world but the extremes appear to be greatest in low latitudes. The range in the number of hurricanes damaging Australia, for example, has been from one hurricane in 1907 and 1919 to seven in 1916 and eleven in 1912. In Fiji some years have none, but several years have had three each and one year four. In the South Indian Ocean the variation reported by the Mauritius Observatory has been from one storm in 1900 to eight in 1894 (and several other years) and to thirteen in 1913. In the Philippines in a 15-year period the number of very severe typhoons varied from one in 1916 to seven each in 1908 and 1911. In respect to less violent cyclonic storms there appears to be a somewhat similar range. For example, the total number of well-marked tropical cyclones occurring in Queensland, Australia, varied from eight in 1920 to 24 in 1916. In respect to the month of occurrence, as well as in annual frequency, there likewise is marked irregularity. In some years cyclones may be lacking during the months when they normally are most frequent and occur only in months supposed to be

free from dangerous storms. Of thunder storms also there is marked variation, perhaps more than in higher latitudes. Many stations in Fiji and elsewhere have experienced several times as many in one year as in another. While many hurricanes are accompanied by appalling lightning, other equally severe hurricanes have none.

Slight changes of weather are almost constantly taking place in the tropics. A rainy spell will be succeeded by a less rainy one or by a few rainless days; a hot spell by a slightly cooler one; a spell of fitful breezes, by several days of steady winds. Such changes have been noticed by the writer in Jamaica, Hawaii, the Philippines, the East Indies, Queensland and elsewhere, but have been especially studied in Fiji. There, a study of the official records taken at Suva reveals an average of about 20 distinct spells of weather well distributed throughout the year, with about as many less distinct changes.

In conclusion, when all these types of variation occur, is it right to give the impression that tropical climates are extremely uniform? But although tropical climates are not so uniform as has been supposed, it does not follow that they are better adapted to civilized man than has been supposed. Most of the variability within the tropics is of a highly irregular sort compared with the variability characteristic of the parts of the higher latitudes where civilized man mostly lives. Indeed it appears that tropical climates are unfavorable for a high type of civilization not alone because of the high temperatures and the general lack of stimulating seasonal changes in temperatures, but also because of the often extreme undependability of the rainfall, the occurrence not infrequently of destructive windstorms and other unfavorable variations. But, nevertheless, highly civilized man can cope with the numerous problems of the tropics far better than can primitive people. Indeed, the latter, unaided, have made little progress. Hence fuller utilization of the tropical resources awaits a greater participation by civilized man.